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STUDIES ON THE DIGESTIBILITY OF THE GRAIN SORGHUMS.

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INTRODUCTION.

As the result of many attempts to find crops suitable for cultivation in the semiarid regions of the Western States of this country, the non-saccharine grain sorghums have been successfully introduced from South Africa, where they have for a long time held a prominent place as a staple cereal crop. In India, China, and other oriental countries the sorghums have been used in both animal and human nutrition, oftentimes comprising the major portion of the available supply of food suitable for human consumption. As an instance of their importance, Lapique [1] states that the dietary of the Abyssinians is essentially a vegetarian one composed largely of durra (*Sorghum vulgare*). In an exploring expedition through China Meyer [2] observed that one of the sorghums, kaoliang, was extensively used for human food. In some localities it was prepared as a mush and eaten by the very poor coolies with such condiments as gingerroot, garlic, and radishes. By people slightly better off this sorghum was ground into a meal and made into a bread. In both instances Meyer observed that exceptionally large quantities of the grain were consumed, making an even more bulky diet than most strictly

[1] Compt. Rend. Soc. Biol. [Paris], 5 (1893), No. 9, pp. 251-258. [2] Personal communication.

vegetarian diets, and he believed accordingly that kaoliang was very incompletely utilized by the human system.

In this country feterita, kafir, dwarf milo, and kaoliang are well-known varieties of the grain sorghums which have for some time been used primarily as feeding crops for animals, but which in some instances have formed a part of the human dietary. The people living in those sections of the country where the sorghums have been grown have long known that these grains are suitable for use as food, and the agricultural press has from time to time reported successful attempts to use them for this purpose. Moreover, following the introduction of the sorghums into the agriculture of the United States, commercial attempts have been made to interest the public in these grains for bread making and similar uses.

Numerous tests of these grains have been made to determine their composition and nutritive value as a feeding crop for animals and, in some instances, to learn how they may best be prepared for human consumption. Many baking tests, for example, have been made with the meal of kafir, which is perhaps the best known of the sorghums, to determine whether it can be used more advantageously alone or mixed with some other meal in ordinary baking practices. The Department of Agriculture[1] has studied the preparation and uses of kafir meal, reporting a number of recipes for incorporating it in such common foods as bread, doughnuts, cookies, etc. A series of baking tests described by Dillon[2] indicates that kafir meal in admixture with wheat flour in the proportion of 1 to 1, 1 to 2, or 2 to 1, makes a very satisfactory bread. Francis[3] reports analyses comparing the composition and food value of feterita, Indian corn, kafir, and wheat, and gives recipes for the preparation of bread and similar products, using part feterita meal and part wheat flour. He concludes that feterita resembles corn in composition, having a nutritive value of about 90 per cent of that of corn, and suggests, moreover, that feterita, being somewhat softer than kafir, should be more thoroughly digested. General information and a number of tested recipes compiled from various sources are given by Davis[4] regarding the value of kafir, feterita, and milo as cereal foods. Summers[5] reports comparative analyses of feterita and wheat together with the results of a series of baking tests. He found that the best bread, pancakes, or gems, could be made by using 50 per cent of feterita meal and 50 per cent of wheat flour. Similar studies of kaoliang are reported by Fromme[6], who used kaoliang meal in place of kafir meal in the recipes reported by the Office of Home Economics.

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[1] U. S. Dept. Agr., Farmers' Bul. 559 (1913), pp. 6, 7.
[2] Northwest. Miller, 90 (1912),) No. 2, pp. 79, 80.
[3] Oklahoma Sta. Circ. 27 (1914), pp. 8.
[4] Texas Dept. Agr. Bul. 42 (1915), p. 18.
[5] Oper. Miller, 20 (1915), No. 1, pp. 42–44.
[6] South Dakota Agr. Expt. Sta. Bul. 158 (1915), pp. 170–174.

The results of these investigations as a whole indicate that while it is best to use some wheat flour to make up for the lack of gluten in the sorghum meal a fairly large proportion of the meal may be satisfactorily used in admixture with wheat flour in the preparation of common foods.

According to Davis [1] it has been noted that dwarf kafir will pop like pop corn. Tests made in connection with the work of the department showed that this was true of dwarf kafir and of feterita and dwarf milo as well, while kaoliang, it was found, scorched without popping. The kafir when popped was tender and of good flavor, closely resembling ordinary pop corn in miniature. Fewer kernels of feterita and dwarf milo popped, and the taste of these, moreover, was comparatively raw and less agreeable than that of the kafir. The kaoliang became quite crisp and tender without popping and had an agreeable taste. It should be noted in trying to pop the sorghums that, owing to the small size of the grain, the popper should be lined with wire netting to prevent its falling through. In similar tests with some of the millets no noticeable success was obtained in trying to pop the grains.

Since a survey of the literature indicates that while digestion experiments with animals are fairly common, few if any studies with man have been reported, it seemed desirable to determine experimentally the digestibility of the grain sorghums, preparing them in different ways for eating, in order to secure data as to their value in human nutrition.

MILLING THE GRAIN SORGHUMS.

Realizing that considerable differences in the chemical composition of any grain occur as a result of variations in climatic and soil conditions, an attempt was made to obtain a supply of the different grains grown under identically the same conditions, and through the cooperation of the Bureau of Plant Industry standardized grain was secured from the cereal field station at Amarillo, Tex. All the grains, including the corn and wheat which were used for comparison, were milled in the Bureau of Chemistry, the same mill being used for each grain and especial care exercised to secure meals of the same fineness. Milled in this way, the product in each case more nearly resembled meal than flour; consequently "meal" will be the descriptive term used throughout this discussion. A record was kept of the proportions of the different grains passing through the 16, 20, 40, 70, and 109 mesh sieves, but only that portion of the meal which passed through the 16-mesh sieve (that is, the size of sieve commonly used by the housekeeper) was used in the preparation of the experimental diet. The amount of kafir bran retained on the sieve and considered too coarse to use in the digestion experiments was about 21 per cent

[1] Texas Dept. Agr. Bul. 42 (1915), pp. 18.

of the total. In the case of the other grain sorghums the values were, milo, 19 per cent; feterita, 15 per cent; and kaoliang, 5 per cent. That these different proportions of the four meals prepared in the same mill should be obtained under similar conditions is most likely due to the structure of the grain, for, although the break was made in the same way, the different grains did not fracture evenly along the same lines. The protein content of the meal, which depends partly upon the quantity of bran removed in the process of milling, was proportionately less in the kafir and milo meals than in the others, since more bran was removed from them on the sieve.

COOKING TESTS AND THE EXPERIMENTAL DIETS.

Before deciding upon the experimental diet a series of tests was undertaken to determine a good method of preparing the sorghum meals for eating and also a suitable combination of foods to serve as a basal ration in the digestion experiments. Results previously reported from the Office[1] of Home Economics indicated that dwarf kafir requires a more thorough cooking than is customary for Indian corn, and that it is often desirable to make a mush of the meal as a foundation for other dishes (yeast bread, gingerbread, etc.). In view of this experience, a mush was first made of one of the sorghum meals (kafir) by cooking 3 cups of meal, 3 cups of water, a little salt, and 3 tablespoonfuls of lard for a half-hour in a double boiler. The lard was simply placed on top of the other ingredients, not mixed with them, for it was noted that when the lard melted it floated on top and prevented excessive evaporation. Baking powder was then beaten into the mush and the bread was baked, but because of the lack of gluten in the kafir meal difficulty was experienced in making such bread light. The addition of glutinous flours, eggs, milk, or other substances containing protein was not desirable, for it was recognized that the presence of protein from any other source than the sorghum grain would complicate the problem of determining the digestibility of the grain protein. It was found, however, that by the above method suitable bread resembling corn bread could be made, providing the batter was baked in a very thin layer. Owing to the loss of practically all the water originally present the bread was extremely dry, hard, and crusty and contained practically no crumb. It was used only in the first series of experiments with kafir meal, when this sorghum was eaten with a basal ration containing only milk, fruit (oranges), and a little sugar to make the diet palatable.

The experience gained in these and earlier cooking tests made it evident that in order to cook the grain sorghums thoroughly a preliminary softening by boiling is desirable, or else it is necessary to have sufficient water present to soften the grain during the baking

[1] U. S. Dept. Agr. Farmer's Bul. 559 (1913), pp. 6, 7.

and to prevent the drying out and hardening of the loaf. In most of the digestion experiments with the sorghum breads, accordingly, the bread was made by the following recipe, which it will be noted contains ginger added to make the bread more palatable:

SORGHUM BREAD.

15 cups meal.	3¾ teaspoons salt.
3¾ teaspoons soda.	5 teaspoons ginger.
1⅞ cups molasses.	1 scant cup lard (melted in).

1⅞ quarts hot water (added to above mixture).

In this series of tests the bread was baked about 1½ hours, without preliminary cooking in the double boiler. The loss of water by evaporation usually caused it to lose from one-fifth to one-sixth of its original weight, but moisture enough remained after the baking to give a bread composed almost entirely of crumb and sufficiently moist to be palatable. Although the bread contained no glutinous material as a binder and tended to crumble when hot, it could easily be cut without much crumbling when cold. Six similar lots of bread were prepared from dwarf kafir, feterita, dwarf milo, kaoliang, corn, and wheat meals, and eaten as a part of a simple mixed diet. The basal ration was composed of apple sauce, potatoes, and butter and furnished only a small fraction of all the protein in the diet, namely, about 20 per cent, which was derived very largely from the potatoes. Although theoretically it would have been even better to eliminate all protein from the basal ration in order to make possible an absolutely direct determination of the digestibility of true grain protein, it was not considered practicable to make use of a protein-free basal ration in these experiments, as such a diet would not have been palatable.

Since it seemed desirable to determine whether the method of preparing the meals for eating materially influenced their digestibility, experiments were also made with the sorghums cooked in the form of a mush. It was found that a satisfactory mush could be prepared in the usual household way as follows: About 15 cups of meal, with salt for seasoning, were mixed with somewhat more boiling water than could be absorbed, and this was cooked for three to four hours in a double boiler which kept the temperature of the mush just below the boiling point for the entire cooking period. The basal ration eaten with the mushes in the digestion experiments consisted of apple sauce, butter, and a cane-sugar sirup—essentially the same ingredients as were used in the experiments with the different kinds of bread. By omitting the potatoes from the ration, however, the amount of protein from accessory foods was greatly reduced, so that 98 to 99 per cent of the total protein consumed was supplied by the grain protein.

SUBJECTS OF THE EXPERIMENTS.

The seven subjects who assisted in the digestion experiments had acquired experience in work of this kind from the tests conducted in the Office of Home Economics with animal fats.[1] They were young men of medium weight and of good health, capable of following instructions carefully, and well informed as to the details and conditions of the experiments. As usual in work of this kind, they were informed that regularity in all of their daily habits was highly desirable. No prescribed hour for eating or regular exercise other than that ordinarily obtained in pursuance of their daily routine was required.

METHODS OF PROCEDURE.

The methods employed closely resembled those tested and found satisfactory in the experiments with the fats. In order to obtain a uniform product the ingredients of the breads and mushes were thoroughly mixed, and care was taken to maintain a constant temperature during the cooking process. In each instance sufficient material was prepared at one time to supply all the subjects for the entire test period. The quantity of the bread or mush eaten was not restricted nor were any of the other components of the diet limited except the potato. In the diets of which the latter formed a part it was given in restricted quantities, so that the potato protein should not form too large a proportion of the total protein content of the diet.

No attention was paid to the maintenance of nitrogen equilibrium, nor were collections and analyses of the urine made to determine what percentage of energy, owing to the occurrence of incompletely oxidized nitrogen in the urine, was not available. Factors based on the results of earlier work were used to estimate indirectly the amount of energy actually available to the body. A record of body weights was not kept, for the purpose of the investigation was primarily the determination of the coefficients of digestibility of the grain sorghums. The 3-day or 9-meal period was judged to be of sufficient duration to permit of accurate analytical results, and since the ration was made up to resemble closely the ordinary mixed diet, preliminary and final periods were omitted.

All analyses were made according to the methods outlined by the Association of Official Agricultural Chemists.[2] Separation of the feces of a test period was accomplished by the use of charcoal taken in gelatin capsules with the first meal of the experiment and with the first meal succeeding the 3-day period. Samples of the bread and of the air-dried feces were analyzed, but the composition of the potato, apple sauce, and butter was estimated by comparison with the average values of a large number of earlier analyses.[3] Allowances were made

[1] U. S. Dept. Agr. Bul. 310 (1915).
[2] U. S. Dept. Agr., Bur. Chem. Bul. 107 (1912).
[3] U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1906).

for changes in the composition of the apples and potatoes taking place during the preparation for eating.

The two common methods for determining the coefficients of digestibility of any single food contained in a mixed diet are, applying the factors obtained in a direct determination of the availability of the basal ration (digestion experiments with the basal ration alone), and using factors for the digestibility of the basal ration which were determined by averaging the results of earlier experimental data. In the experiments reported in this paper the latter method was used. The digestibility of the bread alone was estimated by assuming the following values for the digestibility of the accessory food materials: The protein of potatoes, 83 per cent; the protein of milk and butter, 97 per cent; the protein of fruit, 85 per cent; the carbohydrate of potatoes, 95 per cent; and the carbohydrate of milk and cane sugar, 98 per cent. These assumed values are not absolute, but are close approximations based on the results of a large amount of reliable experimental work.[1]

The method of estimating the digestibility of the bread alone is indicated by the following equations:

[Weight of protein in accessory food materials] × [Percentage of undigested protein in each] = [Protein in feces from food other than bread.

[Total protein in feces] − [Protein in feces from food other than bread] = [Weight of undigested bread protein.]

[Weight of protein in bread] − [Weight of undigested bread protein] ÷ [Weight of protein in bread] = [Estimated percentage of availability of bread protein.] This value, and a similarly computed one for the digestibility of the bread carbohydrate, are given in the tables and are taken as the coefficients of availability of the protein and carbohydrate in the grains. Since the quantity of lard used in making the bread was greatly in excess of the fat content of the grain, it seemed relatively unimportant to estimate the digestibility of the fat of the grain. In view of the fact that the diet contained accessory foods supplying considerable quantities of both carbohydrate and fat, the digestibility of these constituents from the total diet should be approximately the same as has been found for the ordinary mixed diet,[2] namely, 97 and 95 per cent.

DIGESTIBILITY OF THE SORGHUM MEALS PREPARED AS BREADS.

DIGESTION EXPERIMENTS WITH HARD KAFIR BREAD.

The first series of tests with kafir bread included seven 3-day experiments with four different subjects. The bread formed a part of a simple mixed diet containing milk, fruit (oranges), and sugar. As noted on page 4, this bread was thin and had thick, hard crusts

[1] Connecticut Storrs Sta. Rpt. 1899, p. 104.

[2] Connecticut Storrs Sta. Rpt. 1901, p. 245.

but practically no crumb, and since it proved to be rather brittle and tasteless, such bread was not used in the studies with the other sorghums. The data of the experiments are given in the following tables:

Data of digestion experiments with hard kafir bread in a simple mixed diet containing milk.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 89, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kafir bread	1,447.1	292.0	146.6	144.7	842.9	20.9
Milk	4,326.8	3,764.3	142.8	173.1	216.3	30.3
Orange	333.5	289.8	2.7	.7	38.7	1.6
Sugar	33.9	.....	.....	.....	33.9	.....
Total food consumed	6,141.3	4,346.1	292.1	318.5	1,131.8	52.8
Feces	102.9	.....	39.9	20.4	26.9	15.7
Amount utilized	.....	.....	252.2	298.1	1,104.9	37.1
Digestibility of entire ration (per cent)	.....	.....	86.3	93.6	97.6	70.3
Estimated digestibility of bread alone (per cent)	.....	.....	76.0	.....	97.9	.....
Experiment No. 90, subject I. D. B.:						
Kafir bread	1,177.5	237.6	119.3	117.7	685.9	17.0
Milk	4,309.3	3,749.1	142.2	172.4	215.4	30.2
Orange	1,289.4	1,120.5	10.3	2.6	149.6	6.4
Sugar	201.7	.....	.....	.....	201.7	.....
Total food consumed	6,977.9	5,107.2	271.8	292.7	1,252.6	53.6
Feces	161.8	.....	73.2	24.6	45.9	18.1
Amount utilized	.....	.....	198.6	268.1	1,206.7	35.5
Digetibility of entire ration (per cent)	.....	.....	73.1	91.6	96.3	66.2
Estimated digestibility of bread alone (per cent)	.....	.....	43.5	.....	96.7	.....
Experiment No. 91, subject W. D.:						
Kafir bread	914.6	184.6	92.6	91.5	532.7	13.2
Milk	4,335.3	3,771.7	143.1	173.4	216.8	30.3
Orange	1,389.3	1,207.3	11.1	2.8	161.2	6.9
Sugar	.....	.....	.....	.....	.....	.....
Total food consumed	6,639.2	5,163.6	246.8	267.7	910.7	50.4
Feces	102.7	.....	38.0	20.0	28.1	16.6
Amount utilized	.....	.....	208.8	247.7	882.6	33.8
Digestibility of entire ration (per cent)	.....	.....	84.6	92.5	96.9	67.1
Estimated digestibility of bread alone (per cent)	.....	.....	65.4	.....	98.6	.....
Experiment No. 92, subject E. E. M.:						
Kafir bread	1,135.2	229.1	115.0	113.5	661.2	16.4
Milk	4,294.0	3,735.8	141.7	171.8	214.7	30.0
Orange	1,515.6	1,317.1	12.1	3.0	175.8	7.6
Sugar	195.2	.....	.....	.....	195.2	.....
Total food consumed	7,140.0	5,282.0	268.8	288.3	1,246.9	54.0
Feces	124.6	.....	57.0	15.8	34.5	17.3
Amount utilized	.....	.....	211.8	272.5	1,212.4	36.7
Digestibility of entire ration (per cent)	.....	.....	78.8	94.5	97.2	68.0
Estimated digestibility of bread alone (per cent)	.....	.....	55.7	.....	98.7	.....
Experiment No. 98, subject I. D. B.:						
Kafir bread	1,307.3	164.7	152.9	320.3	643.2	26.2
Milk	4,305.3	3,745.6	142.1	172.2	215.3	30.1
Orange	1,466.5	1,274.4	11.7	3.0	170.1	7.3
Sugar	207.8	.....	.....	.....	207.8	.....
Total food consumed	7,286.9	5,184.7	306.7	495.5	1,236.4	63.6
Feces	181.8	.....	93.2	26.2	43.3	19.1
Amount utilized	.....	.....	213.5	469.3	1,193.1	44.5
Digestibility of entire ration (per cent)	.....	.....	69.6	94.7	96.5	70.0
Estimated digestibility of bread alone (per cent)	.....	.....	43.0	.....	97.2	.....

Data of digestion experiments with hard kafir bread in a simple mixed diet containing milk—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 99, subject W. D.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kafir bread	798.3	100.6	93.4	195.6	392.7	16.0
Milk	4,320.6	3,758.9	142.6	172.8	216.0	30.3
Orange	1,459.4	1,268.2	11.7	2.9	169.4	7.2
Sugar	.....	.....	.....	.....	.....	.....
Total food consumed	6,578.3	5,127.7	247.7	371.3	778.1	53.5
Feces	106.8	.....	36.5	23.0	29.3	18.0
Amount utilized	.....	.....	211.2	348.3	748.8	35.5
Digestibility of entire ration (per cent)	.....	.....	85.3	93.8	96.2	66.4
Estimated digestibility of bread alone (per cent)	.....	.....	67.5	.....	97.9	.....
Experiment No. 100, subject E. E. M.:						
Kafir bread	1,032.6	130.1	120.8	253.0	508.0	20.7
Milk	4,314.0	3,753.2	142.3	172.6	215.7	30.2
Orange	1,471.7	1,278.9	11.8	2.9	170.7	7.4
Sugar	173.4	.....	.....	.....	173.4	.....
Total food consumed	6,991.7	5,162.2	274.9	428.5	1,067.8	58.3
Feces	133.3	.....	54.8	20.4	37.8	20.3
Amount utilized	.....	.....	220.1	408.1	1,030.0	38.0
Digestibility of entire ration (per cent)	.....	.....	80.1	95.2	96.5	65.2
Estimated digestibility of bread alone (per cent)	.....	.....	59.7	.....	97.5	.....
Average food consumed per subject per day	2,274.1	1,684.4	90.9	117.3	363.1	18.4

Summary of digestion experiments with hard kafir bread in a simple mixed diet containing milk.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
89	R. L. S.	76.0	97.9	99	W. D.	67.5	97.9
90	I. D. B.	43.5	96.7	100	E. E. M.	59.7	97.5
91	W. D.	65.4	98.6				
92	E. E. M.	55.7	98.7		Average	58.7	97.8
98	I. D. B.	43.0	97.2				

As indicated in the summary table, the average estimated values for the digestibility of kafir bread alone were 58.7 per cent for the protein and 97.8 per cent for the carbohydrate. The bread supplied an average of 40 grams of protein and 203 grams of carbohydrate daily. The usual figures for the percentage of digestibility of the nutrients of cereals are 85 per cent for protein, 90 per cent for fat, and 98 per cent for carbohydrates.[1] On the whole, these experiments and those that follow indicate that the carbohydrate of the grain sorghums is practically as completely utilized for food as can be expected with any cereal product, but that the grain protein is very incompletely digested. In the comparative experiments which follow the bread was prepared by a different recipe.

[1] Connecticut Storrs Sta. Rpt. 1899, p. 104.

DIGESTION EXPERIMENTS WITH SOFTER KAFIR BREAD.

In the second series of tests with dwarf kafir a gingerbread made by the recipe on page 5 was eaten with a basal ration containing potatoes, apple sauce, butter, and sugar. Since the ration contained no milk, it supplied considerably less protein than was furnished in the preceding experiments; and the diet proved so satisfactory that bread was made in the same way for use in the tests with the other sorghums and in the experiments with corn and wheat meals which were made for the purpose of comparison. The data of the experiments with kafir bread are reported in the following tables:

Data of digestion experiments with softer kafir bread in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 187, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kafir bread	1,470.0	512.1	105.7	93.5	719.7	39.0
Potato	917.0	687.7	27.5	.....	192.6	9.2
Apple sauce	1,165.0	1,048.5	3.5	3.5	107.2	2.3
Butter	351.0	38.6	3.5	298.4	.....	10.5
Sugar	199.0	.....	.....	.....	199.0	.....
Total food consumed	4,102.0	2,286.9	140.2	395.4	1,218.5	61.0
Feces	45.0	.....	19.8	4.2	16.2	4.8
Amount utilized	.....	.....	120.4	391.2	1,202.3	56.2
Digestibility of entire ration (per cent)	.....	.....	85.9	98.9	98.7	92.1
Estimated digestibility of bread alone (per cent)	.....	.....	90.8	.....	98.7	.....
Experiment No. 188, subject R. L. S.:						
Kafir bread	1,191.0	414.9	85.6	75.8	583.1	31.6
Potato	792.0	594.0	23.8	.....	166.3	7.9
Apple sauce	1,108.0	997.2	3.3	3.3	101.9	2.3
Butter	233.0	25.6	2.3	198.1	.....	7.0
Sugar	157.0	.....	.....	.....	157.0	.....
Total food consumed	3,481.0	2,031.7	115.0	277.2	1,008.3	48.8
Feces	144.0	.....	62.2	14.1	53.2	14.5
Amount utilized	.....	.....	52.8	263.1	955.1	34.3
Digestibility of entire ration (per cent)	.....	.....	45.9	94.7	94.7	70.3
Estimated digestibility of bread alone (per cent)	.....	.....	38.0	.....	94.6	.....
Experiment No. 189, subject O. E. S.:						
Kafir bread	1,325.0	461.6	95.3	84.3	648.7	35.1
Potato	839.0	629.2	25.2	.....	176.2	8.4
Apple sauce	1,113.0	1,001.7	3.3	3.4	102.4	2.2
Butter	278.0	30.6	2.8	236.3	.....	8.3
Sugar	192.0	.....	.....	.....	192.0	.....
Total food consumed	3,747.0	2,123.1	126.6	324.0	1,119.3	54.0
Feces	164.0	.....	68.3	15.7	64.6	15.4
Amount utilized	.....	.....	58.3	308.3	1,054.7	38.6
Digestibility of entire ration (per cent)	.....	.....	46.0	95.2	94.2	71.5
Estimated digestibility of bread alone (per cent)	.....	.....	38.2	.....	93.6	.....
Experiment No. 190, subject R. F. T.:						
Kafir bread	1,018.0	354.7	73.2	64.7	498.4	27.0
Potato	547.0	410.2	16.4	.....	114.9	5.5
Apple sauce	1,235.0	1,111.5	3.7	3.7	113.6	2.5
Butter	168.0	18.5	1.7	142.8	.....	5.0
Sugar	179.0	.....	.....	.....	179.0	.....
Total food consumed	3,147.0	1,894.9	95.0	211.2	905.9	40.0
Feces	134.5	.....	54.3	20.7	45.0	14.5
Amount utilized	.....	.....	40.7	190.5	860.9	25.5
Digestibility of entire ration (per cent)	.....	.....	42.8	90.2	95.0	63.7
Estimated digestibility of bread alone (per cent)	.....	.....	37.4	.....	95.1	.....

Data of digestion experiments with softer kafir bread in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 211, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kafir bread	1,736.0	583.3	139.9	96.4	871.8	44.6
Potato	1,008.0	756.0	30.2	.....	211.7	10.1
Apple sauce	798.0	718.2	2.4	2.4	73.4	1.6
Butter	330.0	36.3	3.3	280.5	.....	9.9
Sugar	201.0	.....	.....	.....	201.0	.....
Total food consumed	4,073.0	2,093.8	175.8	379.3	1,357.9	66.2
Feces	135.0	.....	66.2	9.8	33.0	26.0
Amount utilized	.....	.....	109.6	369.5	1,324.9	40.2
Digestibility of entire ration (per cent)	.....	.....	62.3	97.4	97.6	60.7
Estimated digestibility of bread alone (per cent)	.....	.....	59.0	.....	98.7	.....
Experiment No. 212, subject R. L. S.:						
Kafir bread	1,354.0	454.9	109.1	75.2	680.0	34.8
Potato	753.0	564.8	22.6	.....	158.1	7.5
Apple sauce	1,122.0	1,009.8	3.4	3.4	103.2	2.2
Butter	209.0	23.0	2.1	177.6	.....	6.3
Sugar	182.0	.....	.....	.....	182.0	.....
Total food consumed	3,620.0	2,052.5	137.2	256.2	1,123.3	50.8
Feces	136.0	.....	63.0	18.1	40.6	14.3
Amount utilized	.....	.....	74.2	238.1	1,082.7	36.5
Digestibility of entire ration (per cent)	.....	.....	54.1	92.9	96.4	71.9
Estimated digestibility of bread alone (per cent)	.....	.....	50.5	.....	97.2	.....
Experiment No. 213, subject O. E. S.:						
Kafir bread	1,631.0	548.0	131.5	90.5	819.1	41.9
Potato	974.0	730.5	29.2	.....	204.5	9.8
Apple sauce	1,145.0	1,030.5	3.4	3.5	105.3	2.3
Butter	280.0	30.8	2.8	238.0	.....	8.4
Sugar	227.0	.....	.....	.....	227.0	.....
Total food consumed	4,257.0	2,339.8	166.9	332.0	1,355.9	62.4
Feces	193.0	.....	83.6	22.5	66.3	20.6
Amount utilized	.....	.....	83.3	309.5	1,289.6	41.8
Digestibility of entire ration (per cent)	.....	.....	49.9	93.2	95.1	67.0
Estimated digestibility of bread alone (per cent)	.....	.....	44.2	.....	95.0	.....
Average food consumed per subject per day	1,258.4	705.8	45.6	103.6	385.2	18.2

Summary of digestion experiments with softer kafir bread in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
187	D. G. G.	90.8	98.7	212	R. L. S.	50.5	97.2
188	R. L. S.	38.0	94.6	213	O. E. S.	44.2	95.0
189	O. E. S.	38.2	93.6				
190	R. F. T.	37.4	95.1		Average	51.2	96.1
211	D. G. G.	59.0	98.7				

In these experiments with the softer kafir bread in a simple mixed diet it will be noted that on an average 46 grams of protein and 385 grams of carbohydrate were supplied the subjects daily. The bread alone furnished 35 grams and 230 grams of these constituents, which were found to be 51.2 per cent and 96.1 per cent digested, respectively. These figures indicate that the bread protein apparently was less available than in the preceding tests in which harder kafir bread was eaten with milk.

DIGESTION EXPERIMENTS WITH FETERITA BREAD.

Feterita was also used in the form of a bread flavored with ginger, experience having shown that all such gingerbreads, owing to their slightly sweet and spicy flavor, are very appetizing. For example, the subjects ate an average of eight-tenths of a pound of the feterita bread per day and over a pound of the kafir bread which was made according to the same recipe. The data of the digestion experiments with feterita bread eaten with a simple mixed diet follow:

Data of digestion experiments with feterita bread in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 195, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feterita bread	1,422.0	477.9	113.4	82.2	705.6	42.9
Potato	918.0	688.5	27.5	.....	192.8	9.2
Apple sauce	888.0	799.2	2.7	2.6	81.7	1.8
Butter	268.0	29.5	2.7	227.8	.....	8.0
Sugar	137.0	.....	.....	.....	137.0	.....
Total food consumed	3,633.0	1,995.1	146.3	312.6	1,117.1	61.9
Feces	124.0	.....	62.2	14.5	34.9	12.4
Amount utilized	.....	.....	84.1	298.1	1,082.2	49.5
Digestibility of entire ration (per cent)	.....	.....	57.5	95.4	96.9	80.0
Estimated digestibility of bread alone (per cent)	.....	.....	52.9	.....	98.0	.....
Experiment No. 196, subject R. L. S.:						
Feterita bread	1,298.0	436.3	103.4	75.0	644.1	39.2
Potato	728.0	546.0	21.8	.....	152.9	7.3
Apple sauce	1,016.0	914.4	3.1	3.0	93.5	2.0
Butter	208.0	22.9	2.1	176.8	.....	6.2
Sugar	128.0	.....	.....	.....	128.0	.....
Total food consumed	3,378.0	1,919.6	130.4	254.8	1,018.5	54.7
Feces	106.0	.....	53.5	12.3	29.4	10.8
Amount utilized	.....	.....	76.9	242.5	989.1	43.9
Digestibility of entire ration (per cent)	.....	.....	59.0	95.2	97.1	80.3
Estimated digestibility of bread alone (per cent)	.....	.....	56.3	.....	98.5	.....
Experiment No. 197, subject O. E. S.:						
Feterita bread	993.0	333.8	79.1	57.4	492.7	30.0
Potato	702.0	526.5	21.1	.....	147.4	7.0
Apple sauce	941.0	846.9	2.8	2.8	86.6	1.9
Butter	204.0	22.4	2.1	173.4	.....	6.1
Sugar	193.0	.....	.....	.....	193.0	.....
Total food consumed	3,033.0	1,729.6	105.1	233.6	919.7	45.0
Feces	110.0	.....	52.9	12.3	32.6	12.2
Amount utilized	.....	.....	52.2	221.3	887.1	32.8
Digestibility of entire ration (per cent)	.....	.....	49.7	94.7	96.5	72.9
Estimated digestibility of bread alone (per cent)	.....	.....	43.1	.....	97.4	.....
Experiment No. 198, subject R. F. T.:						
Feterita bread	856.0	287.7	68.2	49.5	424.8	25.8
Potato	415.0	311.2	12.5	.....	87.1	4.2
Apple sauce	1,018.0	916.2	3.1	3.0	93.7	2.0
Butter	142.0	15.6	1.4	120.7	.....	4.3
Sugar	178.0	.....	.....	.....	178.0	.....
Total food consumed	2,609.0	1,530.7	85.2	173.2	783.6	36.3
Feces	74.0	.....	29.7	11.4	23.5	9.4
Amount utilized	.....	.....	55.5	161.8	760.1	26.9
Digestibility of entire ration (per cent)	.....	.....	65.1	93.4	97.0	74.1
Estimated digestibility of bread alone (per cent)	.....	.....	66.3	.....	98.6	.....

Data of digestion experiments with feterita bread in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 203, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feterita bread	1,205.0	375.0	105.4	68.0	620.3	36.3
Potato	965.0	723.7	29.0	.....	202.7	9.6
Apple sauce	805.0	724.5	2.4	2.4	74.1	1.6
Butter	306.0	33.6	3.1	260.1	.....	9.2
Sugar	165.0	.....	.....	.....	165.0	.....
Total food consumed	3,446.0	1,856.8	139.9	330.5	1,062.1	56.7
Feces	157.0	.....	81.6	11.3	50.6	13.5
Amount utilized	.....	.....	58.3	319.2	1,011.5	43.2
Digestibility of entire ration (per cent)	.....	.....	41.7	96.6	95.2	76.2
Estimated digestibility of bread alone (per cent)	.....	.....	30.7	.....	95.2	.....
Experiment No. 204, subject R. L. S.:						
Feterita bread	1,298.0	403.9	113.6	73.2	668.2	39.1
Potato	913.0	684.8	27.4	.....	191.7	9.1
Apple sauce	888.0	799.2	2.6	2.7	81.7	1.8
Butter	226.0	24.8	2.3	192.1	.....	6.8
Sugar	139.0	.....	.....	.....	139.0	.....
Total food consumed	3,464.0	1,912.7	145.9	268.0	1,080.6	56.8
Feces	94.0	.....	46.8	8.0	29.8	9.4
Amount utilized	.....	.....	99.1	260.0	1,050.8	47.4
Digestibility of entire ration (per cent)	.....	.....	67.9	97.0	97.2	83.5
Estimated digestibility of bread alone (per cent)	.....	.....	66.5	.....	98.6	.....
Experiment No. 205, subject O. E. S.:						
Feterita bread	876.0	272.6	76.6	49.4	451.0	26.4
Potato	836.0	627.0	25.1	.....	175.6	8.3
Apple sauce	827.0	744.3	2.5	2.5	76.1	1.6
Butter	182.0	20.0	1.8	154.7	.....	5.5
Sugar	199.0	.....	.....	.....	199.0	.....
Total food consumed	2,920.0	1,663.9	106.0	206.6	901.7	41.8
Feces	99.0	.....	49.1	8.6	31.2	10.1
Amount utilized	.....	.....	56.9	198.0	870.5	31.7
Digestibility of entire ration (per cent)	.....	.....	53.7	95.8	96.5	75.8
Estimated digestibility of bread alone (per cent)	.....	.....	46.6	.....	97.6	.....
Experiment No. 206, subject R. F. T.:						
Feterita bread	850.0	264.5	74.4	47.9	437.6	25.6
Potato	369.0	276.7	11.1	.....	77.5	3.7
Apple sauce	782.0	703.8	2.3	2.4	71.9	1.6
Butter	136.0	14.9	1.4	115.6	.....	4.1
Sugar	199.0	.....	.....	.....	199.0	.....
Total food consumed	2,336.0	1,259.9	89.2	165.9	786.0	35.0
Feces	110.0	.....	48.5	12.5	36.5	12.5
Amount utilized	.....	.....	40.7	153.4	749.5	22.5
Digestibility of entire ration (per cent)	.....	.....	45.6	92.5	95.4	64.3
Estimated digestibility of bread alone (per cent)	.....	.....	42.1	.....	95.1	.....
Average food consumed per subject per day	1,034.1	577.8	39.5	81.0	319.6	16.2

Summary of digestion experiments with feterita bread in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
195	D. G. G	52.9	98.0	204	R. L. S	66.5	98.6
196	R. L. S	56.3	98.5	205	O. E. S	46.6	97.6
197	O. E. S	43.1	97.4	206	R. F. T	42.1	95.1
198	R. F. T	66.3	98.6				
203	D. G. G	30.7	95.2		Average	50.6	97.4

In the test periods in which feterita bread was eaten, an average of 31 grams of protein and 185 grams of carbohydrate was supplied daily by the bread, the protein being 50.6 per cent and the carbohydrate 97.4 per cent digested. As with the other sorghums, although the meal was coarse and apparently increased the peristaltic action of the intestine, no physiological disturbances were experienced.

DIGESTION EXPERIMENTS WITH MILO BREAD.

Milo bread flavored with ginger was used in this series of tests, being supplemented by a simple mixed diet like that provided for the other experiments of this series. Four subjects assisted in the eight digestion experiments, the results of which are recorded in the following tables:

Data of digestion experiments with milo bread in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 171, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Milo bread	1,247.0	389.4	94.3	79.2	647.9	36.2
Potato	743.0	557.3	22.3	.....	156.0	7.4
Apple sauce	871.0	783.9	2.6	2.6	80.1	1.8
Butter	200.0	22.0	2.0	170.0	.....	6.0
Sugar	252.0	.....	.....	.....	252.0	.....
Total food consumed	3,313.0	1,752.6	121.2	251.8	1,136.0	51.4
Feces	148.0	.....	72.4	12.2	50.2	13.2
Amount utilized	.....	.....	48.8	239.6	1,085.8	38.2
Digestibility of entire ration (per cent)	.....	.....	40.3	95.2	95.6	74.3
Estimated digestibility of bread alone (per cent)	.....	.....	31.5	.....	95.5	.....
Experiment No. 172, subject R. L. S.:						
Milo bread	1,336.0	417.2	101.0	84.8	694.2	38.8
Potato	776.0	582.0	23.3	.....	163.0	7.7
Apple sauce	1,075.0	967.5	3.2	3.2	98.9	2.2
Butter	213.0	23.4	2.1	181.1	.....	6.4
Sugar	100.0	.....	.....	.....	100.0	.....
Total food consumed	3,500.0	1,990.1	129.6	269.1	1,056.1	55.1
Feces	133.0	.....	63.9	21.5	34.4	13.2
Amount utilized	.....	.....	65.7	247.6	1,021.7	41.9
Digestibility of entire ration (per cent)	.....	.....	50.7	92.0	96.7	76.0
Estimated digestibility of bread alone (per cent)	.....	.....	45.5	.....	97.9	.....
Experiment No. 173, subject O. E. S.:						
Milo bread	1,256.0	392.2	95.0	79.8	652.6	36.4
Potato	651.0	488.3	19.5	.....	136.7	6.5
Apple sauce	986.0	887.4	3.0	2.9	90.7	2.0
Butter	226.0	24.8	2.3	192.1	.....	6.8
Sugar	217.0	.....	.....	.....	217.0	.....
Total food consumed	3,336.0	1,792.7	119.8	274.8	1,097.0	51.7
Feces	116.0	.....	55.7	10.7	37.9	11.7
Amount utilized	.....	.....	64.1	264.1	1,059.1	40.0
Digestibility of entire ration (per cent)	.....	.....	53.5	96.1	96.5	77.4
Estimated digestibility of bread alone (per cent)	.....	.....	49.7	.....	97.3	.....
Experiment No. 174, subject R. F. T.:						
Milo bread	1,007.0	314.5	76.1	63.9	523.2	29.3
Potato	443.0	332.3	13.3	.....	93.0	4.4
Apple sauce	1,105.0	994.5	3.3	3.3	101.7	2.2
Butter	150.0	16.5	1.5	127.5	.....	4.5
Sugar	253.0	.....	.....	.....	253.0	.....
Total food consumed	2,958.0	1,657.8	94.2	194.7	970.9	40.4
Feces	119.0	.....	51.2	13.7	42.4	11.7
Amount utilized	.....	.....	43.0	181.0	928.5	28.7
Digestibility of entire ration (per cent)	.....	.....	45.6	93.0	95.6	71.0
Estimated digestibility of bread alone (per cent)	.....	.....	42.3	.....	95.8	.....

Data of digestion experiments with milo bread in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 218, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Milo bread	1,745.0	573.2	130.9	89.3	902.3	49.3
Potato	819.0	606.0	24.6	.....	180.2	8.2
Apple sauce	1,107.0	996.3	3.3	3.3	101.9	2.2
Butter	340.0	37.4	3.4	289.0	.....	10.2
Sugar	185.0	.....	.....	.....	185.0	.....
Total food consumed	4,196.0	2,212.9	162.2	381.6	1,369.4	69.9
Feces	159.0	.....	81.5	11.5	51.4	14.6
Amount utilized	.....	.....	80.7	370.1	1,318.0	55.3
Digestibility of entire ration (per cent)	.....	.....	49.8	97.0	96.2	79.1
Estimated digestibility of bread alone (per cent)	.....	.....	44.8	.....	96.8	.....
Experiment No. 219, subject R. L. S.:						
Milo bread	1,727.0	567.3	129.5	88.4	893.0	48.8
Potato	788.0	583.1	23.6	.....	173.4	7.9
Apple sauce	1,075.0	967.5	3.2	3.2	98.9	2.2
Butter	225.0	24.8	2.2	191.2	.....	6.8
Sugar	110.0	.....	.....	.....	110.0	.....
Total food consumed	3,925.0	2,142.7	158.5	282.8	1,275.3	65.7
Feces	142.0	.....	72.9	15.4	38.8	14.9
Amount utilized	.....	.....	85.6	267.4	1,236.5	50.8
Digestibility of entire ration (per cent)	.....	.....	54.0	94.6	97.0	77.3
Estimated digestibility of bread alone (per cent)	.....	.....	50.6	.....	98.0	.....
Experiment No. 220, subject O. E. S.:						
Milo bread	1,855.0	609.4	139.1	95.0	959.2	52.3
Potato	747.0	552.8	22.4	.....	164.3	7.5
Apple sauce	1,228.0	1,105.2	3.7	3.7	113.0	2.4
Butter	300.0	33.0	3.0	255.0	.....	9.0
Sugar	322.0	.....	.....	.....	322.0	.....
Total food consumed	4,452.0	2,300.4	168.2	353.7	1,558.5	71.2
Feces	216.0	.....	104.6	18.8	71.8	20.8
Amount utilized	.....	.....	63.6	334.9	1,486.7	50.4
Digestibility of entire ration (per cent)	.....	.....	37.8	94.7	95.4	70.8
Estimated digestibility of bread alone (per cent)	.....	.....	31.6	.....	95.2	.....
Experiment No. 221, subject R. F. T.:						
Milo bread	1,435.0	471.4	107.6	73.5	742.0	40.5
Potato	595.0	440.3	17.8	.....	130.9	6.0
Apple sauce	1,128.0	1,015.2	3.4	3.4	103.8	2.2
Butter	240.0	26.4	2.4	204.0	.....	7.2
Sugar	293.0	.....	.....	.....	293.0	.....
Total food consumed	3,691.0	1,953.3	131.2	280.9	1,269.7	55.9
Feces	205.0	.....	89.6	24.1	68.4	22.9
Amount utilized	.....	.....	41.6	256.8	1,201.3	33.0
Digestibility of entire ration (per cent)	.....	.....	31.7	91.4	94.6	59.0
Estimated digestibility of bread alone (per cent)	.....	.....	24.3	.....	93.9	.....
Average food consumed per subject per day	1,223.8	658.5	45.2	95.4	405.5	19.2

Summary of digestion experiments with milo bread in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
171	D. G. G.	31.5	95.5	219	R. L. S.	50.6	98.0
172	R. L. S.	45.5	97.9	220	O. E. S.	31.6	95.2
173	O. E. S.	49.7	97.3	221	F. F. T.	24.3	93.9
174	R. F. T.	42.3	95.8				
218	D. G. G.	44.8	96.8		Average	40.0	96.3

In the diet containing large quantities of milo bread, the bread supplied an average of 36 grams of protein and 251 grams of carbohydrate, which were estimated to be 40.0 per cent and 96.3 per cent digested, respectively. In these experiments, as in the tests with the other sorghums, owing to the low protein content of the grains, it would have been very difficult for the subjects to eat a sufficient bulk of the diet to obtain the amount of protein specified in the common dietary standards, namely, 100 grams per man of average weight daily.

DIGESTION EXPERIMENTS WITH KAOLIANG BREAD.

Kaoliang bread, or, perhaps better, gingerbread (also flavored with ginger), was very similar in taste and appearance to the other sorghum breads. Indeed, all the sorghum gingerbreads so clearly resembled one another that the subjects apparently believed that they were all prepared from the same meal. The essential data of the digestion experiments with four subjects are reported as follows:

Data of digestion experiments with kaoliang bread in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 378, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kaoliang bread	1,419.0	203.6	134.8	124.9	920.4	35.3
Potato	632.0	474.0	19.0	.....	132.7	6.3
Apple sauce	1,045.0	914.4	3.3	4.3	120.5	2.5
Butter	374.0	41.2	3.7	317.9	.....	11.2
Sugar	94.0	.....	.....	.....	94.0	.....
Total food consumed	3,564.0	1,633.2	160.8	447.1	1,267.6	55.3
Feces	194.0	.....	102.5	22.5	53.6	15.4
Amount utilized	.....	.....	58.3	424.6	1,214.0	39.9
Digestibility of entire ration (per cent)	.....	.....	36.3	95.0	95.8	72.2
Estimated digestibility of bread alone (per cent)	.....	.....	26.8	.....	96.4	.....
Experiment No. 379, subject A. J. H.:						
Kaoliang bread	1,323.0	189.9	125.7	116.4	858.1	32.9
Potato	599.0	449.2	18.0	.....	125.8	6.0
Apple sauce	947.0	828.6	3.0	3.9	109.2	2.3
Butter	337.0	37.1	3.4	286.4	.....	10.1
Sugar	44.0	.....	.....	.....	44.0	.....
Total food consumed	3,250.0	1,504.8	150.1	406.7	1,137.1	51.3
Feces	213.0	.....	109.0	34.6	48.3	21.1
Amount utilized	.....	.....	41.1	372.1	1,088.8	30.2
Digestibility of entire ration (per cent)	.....	.....	27.4	91.5	95.8	58.9
Estimated digestibility of bread alone (per cent)	.....	.....	16.1	.....	96.5	.....
Experiment No. 380, subject R. L. S.:						
Kaoliang bread	1,431.0	205.4	135.9	125.9	928.2	35.6
Potato	587.0	440.2	17.6	.....	123.3	5.9
Apple sauce	1,073.0	938.9	3.4	4.4	123.7	2.6
Butter	270.0	29.7	2.7	229.5	.....	8.1
Sugar	121.0	.....	.....	.....	121.0	.....
Total food consumed	3,482.0	1,614.2	159.6	359.8	1,296.2	52.2
Feces	235.0	.....	119.1	30.3	64.0	21.6
Amount utilized	.....	.....	40.5	329.5	1,232.2	30.6
Digestibility of entire ration (per cent)	.....	.....	25.4	91.6	95.0	58.6
Estimated digestibility of bread alone (per cent)	.....	.....	15.0	.....	95.4	.....

Data of digestion experiments with kaoliang bread in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 381, subject O. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kaoliang bread	1,228.0	176.2	116.6	108.1	796.5	30.6
Potato	563.0	422.3	16.9	.....	118.2	5.6
Apple sauce	1,002.0	876.8	3.2	4.1	115.5	2.4
Butter	257.0	28.3	2.6	218.4	.....	7.7
Sugar	183.0	.....	.....	.....	183.0	.....
Total food consumed	3,233.0	1,503.6	139.3	330.6	1,213.2	46.3
Feces	156.0	.....	80.5	19.2	41.5	14.8
Amount utilized	.....	.....	58.8	311.4	1,171.7	31.5
Digestibility of entire ration (per cent)	.....	.....	42.2	94.2	96.6	68.0
Estimated digestibility of bread alone (per cent)	.....	.....	34.0	.....	97.5	.....
Experiment No. 393, subject D. G. G.:						
Kaoliang bread	1,828.0	496.7	139.3	147.5	1,008.0	36.5
Potato	699.0	527.7	17.5	.7	146.1	7.0
Apple sauce	912.0	821.9	2.4	2.9	83.1	1.7
Butter	385.0	42.3	3.8	327.3	.....	11.6
Sugar	167.0	.....	.....	.....	167.0	.....
Total food consumed	3,991.0	1,888.6	163.0	478.4	1,404.2	56.8
Feces	241.0	.....	126.1	23.2	71.5	20.2
Amount utilized	.....	.....	36.9	455.2	1,332.7	36.6
Digestibility of entire ration (per cent)	.....	.....	22.6	95.2	94.9	64.4
Estimated digestibility of bread alone (per cent)	.....	.....	12.0	.....	94.8	.....
Experiment No. 394, subject A. J. H.:						
Kaoliang bread	1,458.0	396.1	111.1	117.7	803.9	29.2
Potato	765.0	577.6	19.1	.8	159.9	7.6
Apple sauce	841.0	757.9	2.2	2.7	76.6	1.6
Butter	244.0	26.9	2.4	207.4	.....	7.3
Sugar	93.0	.....	.....	.....	93.0	.....
Total food consumed	3,401.0	1,758.5	134.8	328.6	1,133.4	45.7
Feces	189.0	.....	97.8	27.6	44.4	19.2
Amount utilized	.....	.....	37.0	301.0	1,089.0	26.5
Digestibility of entire ration (per cent)	.....	.....	27.4	91.6	96.1	58.0
Estimated digestibility of bread alone per cent)	.....	.....	15.2	.....	96.7	.....
Experiment No. 395, subject R. L. S.:						
Kaoliang bread	1,483.0	402.9	113.0	119.7	817.7	29.7
Potato	588.0	443.9	14.7	.6	122.9	5.9
Apple sauce	966.0	870.6	2.5	3.1	88.0	1.8
Butter	297.0	32.7	3.0	252.4	.....	8.9
Sugar	99.0	.....	.....	.....	99.0	.....
Total food consumed	3,433.0	1,750.1	133.2	375.8	1,127.6	46.3
Feces	186.0	.....	97.9	21.4	47.8	18.9
Amount utilized	.....	.....	35.3	354.4	1,079.8	27.4
Digestibility of entire ration (per cent)	.....	.....	26.5	94.3	95.8	59.2
Estimated digestibility of bread alone (per cent)	.....	.....	16.0	.....	96.2	.....
Experiment No. 396, subject O. E. S.:						
Kaoliang bread	1,427.0	387.7	108.7	115.2	786.9	28.5
Potato	712.0	537.6	17.8	.7	148.8	7.1
Apple sauce	946.0	852.5	2.5	3.0	86.2	1.8
Butter	258.0	28.4	2.6	219.3	.....	7.7
Sugar	324.0	.....	.....	.....	324.0	.....
Total food consumed	3,667.0	1,806.2	131.6	338.2	1,345.9	45.1
Feces	171.0	.....	86.8	17.1	50.1	17.0
Amount utilized	.....	.....	44.8	321.1	1,295.8	28.1
Digestibility of entire ration (per cent)	.....	.....	34.0	94.9	96.3	62.3
Estimated digestibility of bread alone (per cent)	.....	.....	23.4	.....	96.5	.....
Average food consumed per subject per day	1,167.5	560.8	48.8	127.7	413.6	16.6

Summary of digestion experiments with kaoliang bread in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
378	D. G. G.	26.8	96.4	394	A. J. H.	15.2	96.7
379	A. J. H.	16.1	96.5	395	R. L. S.	16.0	96.2
380	R. L. S.	15.0	95.4	396	O. E. S.	23.4	96.5
381	O. E. S.	34.0	97.5				
393	D. G. G.	12.0	94.8		Average	19.8	96.3

In the experiments with kaoliang, notwithstanding the fact that the subjects ate nearly a pound of this bread daily, it supplied on an average only 41 grams of protein and 288 grams of carbohydrate per man per day. As the data recorded above show, the bread protein was found to be only 19.8 per cent available to the body, while the digestibility of carbohydrate proved to be 96.3 per cent.

SUMMARY OF DATA ON THE DIGESTIBILITY OF THE GRAIN-SORGHUM BREADS.

Considering the experiments with the sorghum gingerbreads as a whole, the digestibility of the protein of bread alone averaged less than 50 per cent, while that of the carbohydrate constituent of the bread was found to be uniformly high. That the digestibility of the carbohydrate from the sorghum meals alone is practically identical with that of the breads alone is evident from the fact that the only accessory carbohydrate present in the breads was a relatively small quantity of molasses—a carbohydrate whose digestibility is 98 per cent. Moreover the averages for the digestibility of carbohydrate from kafir, feterita, milo, and kaoliang breads are practically identical with the value usually given for the average simple mixed diet—namely, 97 per cent.[1] The close agreement of these values is of particular interest, for it indicates that the low values obtained for the digestibility of protein are not due to errors in the collections of the feces.

The subjects reported as a rule that they seemed to be in normal condition throughout the experimental periods. The diets containing the grain sorghums seemed to assist materially the peristaltic action of the intestine—an effect which was probably due to the large bulk of unassimilated material which the sorghum meals supply. In one or two instances the subjects reported sensations of hunger and nervous headache, but this was probably due to the fact that too little nutritive material was eaten to supply the body needs.

It is thought that sufficient experimental data have been accumulated in this series of experiments to permit of an accurate comparison of the digestibility of the sorghums one with another. In order to ascertain their digestibility as compared with other cereals, a series of check experiments has been made with corn and wheat meal prepared in the same way and eaten with the same basal ration.

[1] Connecticut Storrs Sta. Rpt. 1901, p. 245.

CHECK EXPERIMENTS WITH BREADS MADE FROM CORN AND WHEAT MEALS.

The corn and wheat breads used in the following tests were prepared in the same way as the sorghum gingerbreads (p. 5) and were eaten with the same basal ration of apple sauce, potatoes, and butter. To make certain that the results of these tests should be directly comparable with those of the preceding experiments, the details of the daily routine and all other conditions essential to accurate work were made to correspond nearly exactly. It is to be especially noted that the corn and wheat meals used to make the bread were ground in the same mill as were the sorghum grains and to the same degree of fineness. Such a precaution was necessary in order to remove approximately the same percentage of bran from all of the grains.

Seven digestion experiments, each of the customary three days' duration, were conducted with the cooperation of four subjects. The results of these tests are reported in the following tables:

Data of digestion experiments with corn bread in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 231, subject, D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Corn bread	1,877.0	773.9	86.7	89.9	889.3	37.2
Potato	581.0	430.0	17.4	.....	127.8	5.8
Apple sauce	950.0	855.0	2.9	2.8	87.4	1.9
Butter	355.0	39.0	3.5	301.8	.....	10.7
Sugar	175.0	.....	.....	.....	175.0	.....
Total food consumed	3,938.0	2,097.9	110.5	394.5	1,279.5	55.6
Feces	139.0	.....	45.5	19.2	62.6	11.7
Amount utilized	.....	.....	65.0	375.3	1,216.9	43.9
Digestibility of entire ration (per cent)	.....	.....	58.8	95.1	95.1	79.0
Estimated digestibility of bread alone (per cent)	.....	.....	56.3	.....	95.1	.....
Experiment No. 232, subject, R. L. S.:						
Corn bread	1,957.0	806.9	90.5	93.7	927.2	38.7
Potato	526.0	389.2	15.8	.....	115.7	5.3
Apple sauce	834.0	750.6	2.5	2.5	76.7	1.7
Butter	228.0	25.1	2.3	193.8	.....	6.8
Sugar	82.0	.....	.....	.....	82.0	.....
Total food consumed	3,627.0	1,971.8	111.1	290.0	1,201.6	52.5
Feces	101.0	.....	33.6	16.5	41.5	9.4
Amount utilized	.....	.....	77.5	273.5	1,160.1	43.1
Digestibility of entire ration (per cent)	.....	.....	69.8	94.3	96.5	82.1
Estimated digestibility of bread alone (per cent)	.....	.....	70.1	.....	97.2	.....
Experiment No. 233, subject O. E. S.:						
Corn bread	2,129.0	877.8	98.4	102.0	1,008.7	42.1
Potato	670.0	495.8	20.1	.....	147.4	6.7
Apple sauce	849.0	764.1	2.5	2.6	78.1	1.7
Butter	293.0	32.2	2.9	249.1	.....	8.8
Sugar	344.0	.....	.....	.....	344.0	.....
Total food consumed	4,285.0	2,169.9	123.9	353.7	1,578.2	59.3
Feces	148.0	.....	53.5	21.3	60.8	12.4
Amount utilized	.....	.....	70.4	332.4	1,517.4	46.9
Digestibility of entire ration (per cent)	.....	.....	56.8	94.0	96.1	79.1
Estimated digestibility of bread alone (per cent)	.....	.....	53.2	.....	96.2	.....
Average food consumed per subject per day	1,316.7	693.3	38.4	115.4	451.0	18.6

Summary of digestion experiments with corn bread in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*
231	D. G. G	56.3	95.1
232	R. L. S	70.1	97.2
233	O. E. S	53.2	96.2
	Average	59.9	96.2

Data of digestion experiments with wheat bread in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 226, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Wheat bread	2,035.0	823.4	155.1	110.1	890.2	56.2
Potato	478.0	353.7	14.3	.....	105.2	4.8
Apple sauce	904.0	813.6	2.7	2.7	83.2	1.8
Butter	307.0	33.8	3.1	260.9	.....	9.2
Sugar	193.0	.....	.....	.....	193.0	.....
Total food consumed	3,917.0	2,024.5	175.2	373.7	1,271.6	72.0
Feces	153.0	.....	48.4	13.7	74.7	16.2
Amount utilized	.....	.....	126.8	360.0	1,196.9	55.8
Digestibility of entire ration (per cent)	.....	.....	72.4	96.3	94.1	77.5
Estimated digestibility of bread alone (per cent)	.....	.....	73.0	.....	93.6	.....
Experiment No. 227, subject R. L. S.:						
Wheat bread	1,807.0	731.0	137.8	97.8	790.5	49.9
Potato	509.0	376.6	15.3	.....	112.0	5.1
Apple sauce	909.0	818.1	2.7	2.7	83.7	1.8
Butter	192.0	21.1	1.9	163.2	.....	5.8
Sugar	121.0	.....	.....	.....	121.0	.....
Total food consumed	3,538.0	1,946.8	157.7	263.7	1,107.2	62.6
Feces	71.0	.....	22.1	9.1	31.3	8.5
Amount utilized	.....	.....	135.6	254.6	1,075.9	54.1
Digestibility of entire ration (per cent)	.....	.....	86.0	96.5	97.2	86.4
Estimated digestibility of bread alone (per cent)	.....	.....	88.8	.....	98.1	.....
Experiment No. 228, subject O. E. S.:						
Wheat bread	2,137.0	864.6	163.0	115.6	934.8	59.0
Potato	591.0	437.4	17.7	.....	130.0	5.9
Apple sauce	880.0	792.0	2.6	2.6	81.0	1.8
Butter	262.0	28.8	2.6	222.7	.....	7.9
Sugar	313.0	.....	.....	.....	313.0	.....
Total food consumed	4,183.0	2,122.8	185.9	340.9	1,458.8	74.6
Feces	200.0	.....	61.8	30.5	84.6	23.1
Amount utilized	.....	.....	124.1	310.4	1,374.2	51.5
Digestibility of entire ration (per cent)	.....	.....	66.8	91.1	94.2	69.0
Estimated digestibility of bread alone (per cent)	.....	.....	66.4	.....	93.2	.....
Experiment No. 229, subject R. F. T.:						
Wheat bread	1,401.0	566.8	106.8	75.8	612.9	38.7
Potato	346.0	256.0	10.4	.....	76.1	3.5
Apple sauce	882.0	793.8	2.7	2.6	81.1	1.8
Butter	154.0	17.0	1.5	130.9	.....	4.6
Sugar	220.0	.....	.....	.....	220.0	.....
Total food consumed	3,003.0	1,633.6	121.4	209.3	990.1	48.6
Feces	92.0	.....	26.0	15.6	38.2	12.2
Amount utilized	.....	.....	95.4	193.7	951.9	36.4
Digestibility of entire ration (per cent)	.....	.....	78.6	92.5	96.1	74.9
Estimated digestibility of bread alone (per cent)	.....	.....	81.0	.....	96.4	.....
Average food consumed per subject per day	1,220.1	644.0	53.3	99.0	402.3	21.5

Summary of digestion experiments with wheat bread in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
226	D. G. G.	73.0	93.6	229	R. F. T.	81.0	96.4
227	R. L. S.	88.8	98.1				
228	O. E. S.	66.4	93.2		Average	77.3	95.3

The digestibility of fat and carbohydrate in both the corn and the wheat bread diets was very satisfactory, 94.5 per cent of fat and 95.9 per cent of carbohydrate in the ration containing corn, and 94.1 per cent of fat and 95.4 per cent of carbohydrate in the wheat diet representing the percentages of available nutrients. The estimated value for the digestibility of the carbohydrate of corn bread alone is 96.2 per cent and of the carbohydrate of wheat bread 95.3 per cent.

An average of 38.4 grams of protein per man per day was 61.8 per cent digested in the experiments with corn bread and, although the average daily consumption of protein in the experiments with wheat was only 53.3 grams, this was 76.0 per cent available to the body. The estimated digestibility of the protein supplied by the corn bread alone is 59.9 per cent, and of the protein supplied by wheat bread 77.3 per cent. These values undoubtedly vary with the quantity of bran present in the flour and with other experimental conditions, such as the nature of the diet and the quantity of protein eaten. This opinion is in accordance with the conclusions of other investigators. Results of experiments by Woods and Merrill,[1] conducted in cooperation with the earlier work of the Office of Home Economics, indicate that all kinds of wheat bread are well digested and deserving of the important place given to them in the diet. These investigators found that the digestibility of the protein of wheat bread varied from 93.8 per cent for standard patent to 80 per cent for entire wheat flour. Snyder[2] also studied the comparative digestibility of protein in different grades of wheat flour, finding that although the entire wheat and graham flours contained more protein than the patent flours, the percentages of protein actually available to the body was greater in the patent flour. In experiments with Indian corn meal prepared for eating in several different ways, Merrill[3] found a digestibility of protein varying from 73 to 86 per cent.

The digestibility of corn protein herein determined, 59.9 per cent, is somewhat lower than that usually reported, but it seems reasonable to conclude, in comparison with the preceding experiments with the grain sorghums in identically the same basal ration, that corn protein is more thoroughly digested than are the protein constituents of dwarf

[1] U. S. Dept. Agr., Office Expt. Sta. Bul. 143 (1904), p. 33. [2] Maine Sta. Bul. 131 (1906).
[3] Idem, 126 (1903), p. 46; 156 (1905).

kafir, feterita, dwarf milo, and kaoliang. As indicated by its digestibility, 77.3 per cent, wheat protein is even more completely available to the body. Since the sorghums contain less protein than is found in either corn or wheat, and as these tests indicate that the protein, gram for gram, is less thoroughly digested than that of corn and wheat, it may be concluded that both corn and wheat contain more available protein than do the sorghum grains.

DIGESTIBILITY OF THE SORGHUM MEALS PREPARED AS MUSHES.

DIGESTION EXPERIMENTS WITH KAFIR MUSH.

To ascertain whether or not the method of cooking the sorghum meals influences their digestibility, the series of tests reported in the following pages was made. In these experiments kafir meal from the same lot as that used in the preceding tests was cooked as a mush (p. 5), which was eaten with a basal ration consisting of apple sauce, butter, sirup, and sugar. The diet proved entirely satisfactory for the tests, in that it was sufficiently appetizing to preclude any psychic dislike of the food, so that a nominal quantity of mush was willingly eaten. The same subjects cooperated in these tests and continued the same routine that was followed in the previous experiments.

The experimental data of three experiments with kafir mush are summarized in the following tables:

Data of digestion experiments with kafir mush in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 239, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kafir mush	3,299.0	2,415.9	130.0	1.3	698.1	53.7
Apple sauce						
Butter	248.0	27.3	2.5	210.8		7.4
Sirup	1,617.0	681.0			936.0	
Sugar	135.0				135.0	
Total food consumed	5,299.0	3,124.2	132.5	212.1	1,769.1	61.1
Feces	119.0		52.9	11.4	43.8	10.9
Amount utilized			79.6	200.7	1,725.3	50.2
Digestibility of entire ration (per cent)			60.1	94.6	97.5	82.2
Estimated digestibility of mush alone (per cent)			59.4		96.8	
Experiment No. 240, subject R. L. S.:						
Kafir mush	3,282.0	2,403.4	129.3	1.3	694.5	53.5
Apple sauce	437.0	396.8	1.0	1.3	37.1	.8
Butter	290.0	31.9	2.9	246.5		8.7
Sirup	1,315.0	555.6			759.4	
Sugar	52.0				52.0	
Total food consumed	5,376.0	3,387.7	133.2	249.1	1,543.0	63.0
Feces	119.0		50.0	17.3	38.2	13.5
Amount utilized			83.2	231.8	1,504.8	49.5
Digestibility of entire ration (per cent)			62.5	93.1	97.5	78.6
Estimated digestibility of mush alone (per cent)			61.5		97.4	

Data of digestion experiments with kafir mush in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 241, subject O. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kafir mush	3,089.0	2,262.1	121.7	1.2	653.6	50.4
Apple sauce	1,069.0	970.6	2.6	3.2	90.7	1.9
Butter	156.0	17.1	1.6	132.6	.....	4.7
Sirup	1,580.0	669.7	.....	.....	910.3	.....
Sugar	52.0	.....	.....	.....	52.0	.....
Total food consumed	5,946.0	3,919.5	125.9	137.0	1,706.6	57.0
Feces	196.0	.....	93.5	17.7	65.9	18.9
Amount utilized	.....	.....	32.4	119.3	1,640.7	38.1
Digestibility of entire ration (per cent)	.....	.....	25.7	87.1	96.1	66.8
Estimated digestibility of mush alone (per cent)	.....	.....	23.5	.....	94.2	.....
Average food consumed per subject per day	1,846.8	1,159.1	43.5	66.5	557.6	20.1

Summary of digestion experiments with kafir mush in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*
239	D. G. G.	59.4	96.8
240	R. L. S.	61.5	97.4
241	O. E. S.	23.5	94.2
	Average	48.1	96.1

The results of the data tabulated above show that, while 96.1 per cent of the carbohydrate of kafir mush was digested, an average of only 48.1 per cent of the protein was available to the body. It was found that the mush supplied 42 grams of protein and 227 grams of carbohydrate per man per day.

DIGESTION EXPERIMENTS WITH FETERITA MUSH.

Feterita mush prepared in the manner already described formed a large part of the diet of the following experiments, and the same basal ration, consisting of apple sauce, butter, sirup, and sugar, was eaten with the mush. The following tables record the data of the digestion experiments.

Data of digestion experiments with feterita mush in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 258, subject H. F. B.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feterita mush	2,915.0	1,929.1	131.2	8.7	803.7	42.3
Apple sauce	1,174.0	1,066.0	2.8	3.5	99.6	2.1
Butter	205.0	22.6	2.0	174.3	.....	6.1
Sirup	1,346.0	350.0	.....	.....	996.0	.....
Sugar	220.0	.....	.....	.....	220.0	.....
Total food consumed	5,860.0	3,367.7	136.0	186.5	2,119.3	50.5
Feces	53.0	.....	29.6	4.4	15.0	4.0
Amount utilized	.....	.....	106.4	182.1	2,104.3	46.5
Digestibility of entire ration (per cent)	.....	.....	78.2	97.6	99.3	92.1
Estimated digestibility of mush alone (per cent)	.....	.....	77.5	.....	99.3	.....

Data of digestion experiments with feterita mush in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 259, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Feterita mush	3,027.0	2,003.3	136.2	9.1	834.5	43.9
Apple sauce						
Butter	240.0	26.4	2.4	204.0		7.2
Sirup	1,258.0	327.1			930.9	
Sugar	112.0				112.0	
Total food consumed	4,637.0	2,356.8	138.6	213.1	1,877.4	51.1
Feces	150.0		76.9	16.8	43.3	13.0
Amount utilized			61.7	196.3	1,834.1	38.1
Digestibility of entire ration (per cent)			44.5	92.1	97.7	74.6
Estimated digestibility of mush alone (per cent)			43.6		97.3	
Experiment No. 260, subject R. L. S.:						
Feterita mush	2,490.0	1,647.9	112.0	7.5	686.5	36.1
Apple sauce	853.0	774.5	2.1	2.6	72.3	1.5
Butter	203.0	22.3	2.0	172.6		6.1
Sirup	1,163.0	302.4			860.6	
Sugar	33.0				33.0	
Total food consumed	4,742.0	2,747.1	116.1	182.7	1,652.4	43.7
Feces	125.0		64.9	12.1	36.8	11.2
Amount utilized			51.2	170.6	1,615.6	32.5
Digestibility of entire ration (per cent)			44.1	93.4	97.8	74.4
Estimated digestibility of mush alone (per cent)			42.1		98.3	
Experiment No. 261, subject O. E. S.:						
Feterita mush	2,825.0	1,869.6	127.1	8.5	778.8	41.0
Apple sauce	1,274.0	1,156.8	3.1	3.8	108.0	2.3
Butter	135.0	14.9	1.3	114.8		4.0
Sirup	1,658.0	431.1			1,226.9	
Sugar	166.0				166.0	
Total food consumed	6,058.0	3,472.4	131.5	127.1	2,279.7	47.3
Feces	162.0		88.5	18.8	41.8	12.9
Amount utilized			43.0	108.3	2,237.9	34.4
Digestibility of entire ration (per cent)			32.7	85.2	98.2	72.7
Estimated digestibility of mush alone (per cent)			30.4		99.6	
Average food consumed per subject per day	1,774.7	995.3	43.5	59.1	660.7	16.1

Summary of digestion experiments with feterita mush in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
258	H. F. B.	77.5	99.3	261	O. E. S.	30.4	99.6
259	D. G. G.	43.6	97.3				
260	R. L. S.	42.1	98.3		Average	48.4	98.6

In these experiments an average of 43.5 grams of protein was supplied by the total diet, and of this amount 42.2 grams, or about 97 per cent was derived from the feterita meal and 48.4 per cent digested. The carbohydrate portion of the mush, as in the other tests, was very completely utilized, since an average of 259 grams daily was 98.6 per cent digested.

DIGESTION EXPERIMENTS WITH MILO MUSH.

Milo mush closely resembled the other mushes in appearance and lack of definite flavor. Eaten with sirup and butter, however, it was apparently relished by the four subjects who assisted in the experiments recorded below:

Data of digestion experiments with milo mush in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 254, subject H. F. B.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Milo mush	3,656.0	2,772.0	121.0	25.6	690.6	46.8
Apple sauce	1,021.0	927.1	2.4	3.1	86.6	1.8
Butter	277.0	30.5	2.8	235.4	.....	8.3
Sirup	1,494.0	556.0	.....	.....	938.0	.....
Sugar	209.0	.....	.....	.....	209.0	.....
Total food consumed	6,657.0	4,285.6	126.2	264.1	1,924.2	56.9
Feces	189.0	.....	95.9	18.9	59.2	15.0
Amount utilized	.....	.....	30.3	245.2	1,865.0	41.9
Digestibility of entire ration (per cent)	.....	.....	24.0	92.8	96.9	73.6
Estimated digestibility of mush alone (per cent)	.....	.....	21.2	.....	96.0	.....
Experiment No. 255, subject D. G. G.:						
Milo mush	3,972.0	3,011.6	131.5	27.8	750.3	50.8
Apple sauce	.....	.....	.....	.....	.....	.....
Butter	249.0	27.4	2.5	211.6	.....	7.5
Sirup	1,424.0	520.8	.....	.....	903.2	.....
Sugar	129.0	.....	.....	.....	129.0	.....
Total food consumed	5,774.0	3,559.8	134.0	239.4	1,782.5	58.3
Feces	151.0	.....	79.5	11.8	46.0	13.7
Amount utilized	.....	.....	54.5	227.6	1,736.5	44.6
Digestibility of entire ration (per cent)	.....	.....	40.7	95.1	97.4	76.5
Estimated digestibility of mush alone (per cent)	.....	.....	39.5	.....	96.6	.....
Experiment No. 256, subject R. L. S.:						
Milo mush	2,945.0	2,232.9	97.5	20.6	556.3	37.7
Apple sauce	744.0	675.6	1.8	2.2	63.1	1.3
Butter	201.0	22.1	2.0	170.9	.....	6.0
Sirup	1,225.0	476.5	.....	.....	748.5	.....
Sugar	20.0	.....	.....	.....	20.0	.....
Total food consumed	5,135.0	3,407.1	101.3	193.7	1,387.9	45.0
Feces	102.0	.....	51.9	13.2	26.1	10.8
Amount utilized	.....	.....	49.4	180.5	1,361.8	34.2
Digestibility of entire ration (per cent)	.....	.....	48.8	93.2	98.1	76.0
Estimated digestibility of mush alone (per cent)	.....	.....	47.2	.....	99.2	.....
Experiment No. 257, subject O. E. S.:						
Milo mush	3,642.0	2,761.4	120.5	25.5	688.0	46.6
Apple sauce	1,087.0	987.0	2.6	3.2	92.2	2.0
Butter	166.0	18.2	1.7	141.1	.....	5.0
Sirup	1,473.0	552.9	.....	.....	920.1	.....
Sugar	206.0	.....	.....	.....	206.0	.....
Total food consumed	6,574.0	4,319.5	124.8	169.8	1,906.3	53.6
Feces	167.0	.....	85.3	21.8	45.0	14.9
Amount utilized	.....	.....	39.5	148.0	1,861.3	38.7
Digestibility of entire ration (per cent)	.....	.....	31.7	87.2	97.6	72.2
Estimated digestibility of mush alone (per cent)	.....	.....	29.6	.....	98.9	.....
Average food consumed per subject per day	2,011.7	1,297.7	40.5	72.3	583.4	17.8

Summary of digestion experiments with milo mush in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
254	H. F. B	21.2	96.0	257	O. E. S	29.6	98.9
255	D. G. G	39.5	96.6				
256	R. L. S	47.2	99.2		Average	34.4	97.7

In the above summary it will be noted that an average of 97.7 per cent of the carbohydrates of milo mush was digested and that 34.4 per cent of the milo protein was assimilated by the body. This mush was apparently less digested than that of the preceding experiments and, moreover, it supplied only 39 grams of protein and 224 grams of carbohydrates daily.

DIGESTION EXPERIMENTS WITH KAOLIANG MUSH.

Kaoliang mush was of a light-chocolate color and so had a different appearance from that of the other mushes. Its flavor, however, was not pronounced, but much like that of the mushes made from the other grain sorghums studied. The essential data of eight digestion experiments in which four subjects assisted are recorded in the following tables:

Data of digestion experiments with kaoliang mush in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 385, subject D. G. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kaoliang mush	3,060.0	2,400.9	82.3	27.9	527.5	21.4
Apple sauce	1,013.0	916.3	2.5	3.2	89.1	1.9
Butter	267.0	29.4	2.7	226.9	.....	8.0
Sirup	1,586.0	634.4	.....	.....	951.6	.....
Sugar	129.0	.....	.....	.....	129.0	.....
Total food consumed	6,055.0	3,981.0	87.5	258.0	1,697.2	31.3
Feces	166.0	.....	85.9	19.2	47.1	13.8
Amount utilized	.....	.....	1.6	238.8	1,650.1	17.5
Digestibility of entire ration (per cent)	.....	.....	18.3	92.6	97.2	55.9
Estimated digestibility of mush alone (per cent)	.....	.....	.....	.....	96.9	.....
Experiment No. 386, subject A. J. H.:						
Kaoliang mush	2,388.0	1,873.6	64.3	21.7	411.7	16.7
Apple sauce	931.0	842.1	2.3	2.9	81.9	1.8
Butter	164.0	18.1	1.6	139.4	.....	4.9
Sirup	479.0	191.6	.....	.....	287.4	.....
Sugar	89.0	.....	.....	.....	89.0	.....
Total food consumed	4,051.0	2,925.4	68.2	164.0	870.0	23.4
Feces	149.0	.....	82.0	21.4	32.1	13.5
Amount utilized	.....	.....	.....	142.6	837.9	9.9
Digestibility of entire ration (per cent)	.....	.....	.....	87.0	96.3	42.3
Estimated digestibility of mush alone (per cent)	.....	.....	.....	.....	96.0	.....

Data of digestion experiments with kaoliang mush in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 387, subject R. L. S.:						
Kaoliang mush	2,849.0	2,235.3	76.6	25.9	491.2	20.0
Apple sauce	1,024.0	926.2	2.6	3.2	90.1	1.9
Butter	260.0	28.6	2.6	221.0	.....	7.8
Sirup	396.0	158.4	.....	.....	237.6	.....
Sugar	46.0	.....	.....	.....	46.0	.....
Total food consumed	4,575.0	3,348.5	81.8	250.1	864.9	29.7
Feces	155.0	.....	85.3	19.5	36.3	13.9
Amount utilized	.....	.....	.....	230.6	828.6	15.8
Digestibility of entire ration (per cent)	.....	.....	.....	92.2	95.8	53.2
Estimated digestibility of mush alone (per cent)	.....	.....	.....	.....	95.6	.....
Experiment No. 388, subject O. E. S.:						
Kaoliang mush	2,510.0	1,969.4	67.5	22.8	432.7	17.6
Apple sauce	1,008.0	911.8	2.5	3.1	88.7	1.9
Butter	151.0	16.6	1.5	128.4	.....	4.5
Sirup	1,128.0	451.2	.....	.....	676.8	.....
Sugar	172.0	.....	.....	.....	172.0	.....
Total food consumed	4,969.0	3,349.0	71.5	154.3	1,370.2	24.0
Feces	163.0	.....	83.8	20.9	42.6	15.7
Amount utilized	.....	.....	.....	133.4	1,327.6	8.3
Digestibility of entire ration (per cent)	.....	.....	.....	86.5	96.9	34.6
Estimated digestibility of mush alone (per cent)	.....	.....	.....	.....	96.1	.....
Experiment No. 397, subject D. G. G.:						
Kaoliang mush	2,831.0	2,036.1	109.7	26.3	629.5	29.4
Apple sauce	830.0	756.5	1.9	2.4	67.8	1.4
Butter	175.0	19.2	1.7	148.8	.....	5.3
Sirup	1,266.0	506.4	.....	.....	759.6	.....
Sugar	108.0	.....	.....	.....	108.0	.....
Total food consumed	5,210.0	3,318.2	113.3	177.5	1,564.9	36.1
Feces	199.0	.....	110.3	21.6	51.2	15.9
Amount utilized	.....	.....	3.0	155.9	1,513.7	20.2
Digestibility of entire ration (per cent)	.....	.....	2.6	87.8	96.7	56.0
Estimated digestibility of mush alone (per cent)	.....	.....	.....	.....	95.7	.....
Experiment No. 398, subject A. J. H.:						
Kaoliang mush	1,988.0	1,429.8	77.0	18.5	442.0	20.7
Apple sauce	653.0	595.1	1.5	1.9	53.4	1.1
Butter	208.0	22.9	2.1	176.8	.....	6.2
Sirup	253.0	101.2	.....	.....	151.8	.....
Sugar	54.0	.....	.....	.....	54.0	.....
Total food consumed	3,156.0	2,149.0	80.6	197.2	701.2	28.0
Feces	131.0	.....	71.7	17.4	30.1	11.8
Amount utilized	.....	.....	8.9	179.8	671.1	16.2
Digestibility of entire ration (per cent)	.....	.....	11.0	91.2	95.7	57.9
Estimated digestibility of mush alone (per cent)	.....	.....	7.3	.....	95.3	.....
Experiment No. 399, subject R. L. S.:						
Kaoliang mush	2,822.0	2,029.6	109.4	26.2	627.5	29.3
Apple sauce	760.0	692.7	1.7	2.2	62.1	1.3
Butter	341.0	37.5	3.4	289.9	.....	10.2
Sirup	716.0	286.4	.....	.....	429.6	.....
Sugar	40.0	.....	.....	.....	40.0	.....
Total food consumed	4,679.0	3,046.2	114.5	318.3	1,159.2	40.8
Feces	160.0	.....	86.4	22.7	36.0	14.9
Amount utilized	.....	.....	28.1	295.6	1,123.2	25.9
Digestibility of entire ration (per cent)	.....	.....	24.5	92.9	96.9	63.5
Estimated digestibility of mush alone (per cent)	.....	.....	21.4	.....	96.7	.....

Data of digestion experiments with kaoliang mush in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 400, subject O. E. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Kaoliang mush	2,146.0	1,543.4	83.2	20.0	477.1	22.3
Apple sauce	742.0	676.2	1.7	2.2	60.6	1.3
Butter	198.0	21.8	2.0	168.3	.....	5.9
Sirup	1,036.0	414.4	.....	.....	621.6	.....
Sugar	192.0	.....	.....	.....	192.0	.....
Total food consumed	4,314.0	2,655.8	86.9	190.5	1,351.3	29.5
Feces	154.0	.....	78.2	26.1	35.4	14.3
Amount utilized	.....	.....	8.7	164.4	1,315.9	15.2
Digestibility of entire ration (per cent)	.....	.....	10.0	86.3	97.4	51.5
Estimated digestibility of mush alone (per cent)	.....	.....	6.5	.....	97.4	.....
Average food consumed per subject per day	1,542.0	1,032.2	29.3	71.3	399.1	10.1

Summary of digestion experiments with kaoliang mush in a simple mixed diet.

Experiment No.	Subject.	Protein.	Carbohydrates.	Experiment No.	Subject.	Protein.	Carbohydrates.
		Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
385	D. G. G.	.....	96.9	398	A. J. H.	7.3	95.3
386	A. J. H.	.....	96.0	399	R. L. S.	21.4	96.7
387	R. L. S.	.....	95.6	400	O. E. S.	6.5	97.4
388	O. E. S.	.....	96.1				
397	D. G. G.	.....	95.7		Average	4.4	96.2

The digestibility of the kaoliang protein was found by averaging the eight experiments to be only 4.4 per cent, although the carbohydrate from this source was 96.2 per cent digested; 28 grams of protein and 168 grams of carbohydrate per man per day were supplied by the kaoliang mush. As the subjects reported that they were in normal physical condition during these experiments, it seems reasonable to attribute the incomplete digestibility of the kaoliang protein to the structure of the grain rather than to the chemical nature of the protein molecule. In view of the lack of information, however, regarding the histology of kaoliang and the other grain sorghums, it is difficult at the present time to explain conclusively the differences found for the digestibility of the protein constituent of these cereals.

SUMMARY OF DATA ON THE DIGESTIBILITY OF THE GRAIN-SORGHUM MUSHES.

The results of the experiments with the sorghum mushes show that 48 per cent, 48 per cent, 34 per cent, and 4 per cent of the cereal protein furnished by the rations containing dwarf kafir, feterita, dwarf milo, and kaoliang, respectively, are the estimated values for the digestibility of the protein constituent of the grains. Since these values were determined by as direct a method as is available—98 to 99 per cent of the total protein of the diet was obtained from the

grains—they may be considered to represent the digestibility of protein determined directly rather than estimated. The carbohydrate portion of the diet was as well assimilated as in the ordinary mixed diet, indicating that the very incomplete digestibility of protein was not due to faulty experimental methods. The diet proved to be entirely satisfying, at least for the three-day period, for the subjects reported that they were in normal physical condition throughout the experiments.

Comparing the experiments in which mush was eaten with those in which sorghum gingerbread formed the major portion of the diet, it was found that an average of 41 grams of protein per man per day was supplied in the former and 35 grams in the latter series of experiments. The explanation of such a small consumption of protein lies in the fact that the grain sorghums contain too little protein to make it feasible to obtain, say, 100 grams of protein daily on a diet of this nature. The amounts of energy supplied by the mush and bread diets were 3,000 and 2,850 calories, respectively, an energy value in agreement with the requirements of accepted dietary standards.

SUMMARY AND CONCLUSIONS.

In the experiments in which hard kafir bread was eaten with milk it was found that the protein of this cereal, as distinguished from that of the diet as a whole, was 58 per cent digested. Possibly owing to the large proportion of milk protein in the diet this value for the cereal protein alone may be too high.

In the majority of the experiments the grains under consideration were eaten in the form of softer bread than that mentioned above and also in the form of mushes. Considering the grain sorghums studied the results show that on an average the protein of the softer dwarf kafir bread, as distinguished from the protein of the diet as a whole, was 51 per cent digested and that of the dwarf kafir mush 48 per cent. In the case of the protein of feterita the values were 51 per cent for the bread protein and 48 per cent for the mush protein. With the dwarf milo the values were 40 per cent for the protein of the bread and 34 per cent for that of the mush, and for the kaoliang 20 per cent for the protein of the bread and 4 per cent for that of the mush.

Fat was present in these grains in very small and relatively unimportant quantities and so no attempt was made to estimate the digestibility of this constituent as supplied by the cereals.

In all cases it was found that the carbohydrates of the experimental rations and of the sorghums alone were very completely utilized. Considering the grain only, as distinguished from the ration as a whole, the average value for the dwarf kafir (hard) bread was 98 per cent, for softer dwarf kafir bread 96 per cent, and for dwarf kafir mush 96 per cent. In the case of carbohydrates supplied by feterita, the

average values were 97 per cent for the bread and 99 per cent for the mush; with dwarf milo 96 per cent for the bread and 98 per cent for the mush; and for kaoliang 96 per cent for both bread and mush.

The corn and wheat proteins, in general, were found to be somewhat less thoroughly digested than has usually been found to be the case with these cereals, this being due, no doubt, to the coarseness of the meals used. The average digestibility of the corn-bread protein, as distinguished from that of the diet as a whole, was 60 per cent and of the coarse wheat-bread protein 77 per cent. In the case of the carbohydrates 96 per cent of the total supplied by the corn bread, as distinguished from the diet as a whole, was digested and of the coarse wheat bread 95 per cent.

The experiments with all the grains were conducted under conditions as nearly uniform as possible, with the idea of getting directly comparable results. Hence it may be concluded that the protein of the grain sorghums is less digestible than that contained in either corn or wheat.

The discussion so far has concerned the experimental data principally from a technical standpoint, but the practical application of the results is certainly of equal interest. From the data here recorded and elsewhere available regarding the preparation of the sorghums for the table, it seems fair to conclude that these cereals are decidedly valuable as human food. They can be prepared for the table in palatable form, requiring, however, some special method of cooking to insure their being at their best. In preparing them it is most important to make certain of the absorption of water in such quantities that the particles of meal which are characteristically hard or flinty may be well softened.

To many palates the grain sorghums more nearly resemble buckwheat in flavor than they do corn or wheat. The flavor is quite generally regarded as agreeable, and the grains are conceded to be wholesome. Though their protein is less completely assimilated than that of corn or wheat, they are nevertheless, with the exception of kaoliang, a fairly good source of this nutrient. Furthermore, the sorghums are a good source of carbohydrate and furnish this important food constituent in a form very completely available to the body. The use of the grain sorghums in general offers variety to the diet, and in regions where other cereals are not so successfully grown they may contribute materially to the supply of materials suitable as human food.

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